

# Astronomy 330



This class (Lecture 21):  
Evolution of World View

Next Class:  
Lifetime

**HW #9 due on Wednesday!**

Music: *Concerning the UFO Sighting near Highland, Illinois*  
– Sufjan Stevens

## Question



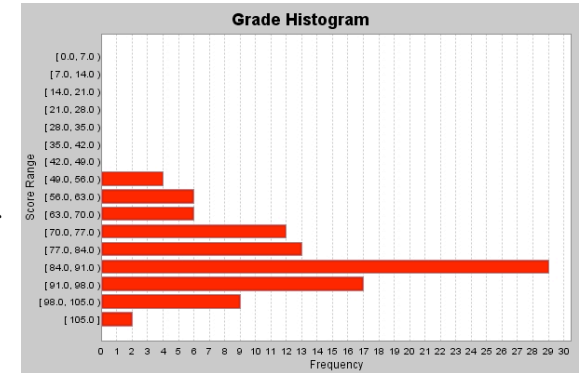
Exam 2 was

- a) too easy. It didn't challenge me. I felt like I wasted time studying for it.
- b) too hard.
- c) about the appropriate or expected level.
- d) too easy, but I like my exams like that.
- e) okay, but it didn't have enough interpretative dance components.

## Exam 2



- Good job again!
- Average was 83% and median of 88%!
- On final, I will replace grade of this exam with grade on Section 2 of final if that is higher.



## Paper Rough Draft



- Worth 1% of your grade, but really worth more.
- **Due tomorrow!**
  - Beginning of discussion class, else considered late.
- Should pretty much be the final paper.
- Will be looking for scope, ease-of-read, scientific reasoning, **proper citation**, and general style.
- 6 to 8 pages double-spaced 12-point font, not including references.

# Paper Rough Draft



- *Mars is a planet without an overzealous monkey population (Holt et al. 2000; James & Mann 2006; Walker 2007; Wikipedia: Mars).*  
– *I expect to see a few refs per page!*

- Holt, W., Smith, E., Rowe, T., & Jones, A. B. 2000, The Astronomical Almanac for the Year 1994, Vol. 2 (2nd ed.; Washington, DC: GPO)
- Smith, A. B., Thomas, J. R., Major, W., & Peebles, P. J. E. 2006, Astrophysics Journal, 450, 12
- Wikipedia: Mars, <http://en.wikipedia.org/wiki/Mars>, Accessed: March 25, 2010, Updated: March 24, 2010

## Drake Equation

That's 8.2 intelligent systems/century

Frank Drake



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
9	stars/yr	0.29 systems/star	1.03 x 0.22 = 0.23 planets/system	0.46 life/planet	0.3 intel./life	comm./intel.	yrs/comm.

## Outline



- Worldview: do we think aliens may be out there?
- What is  $f_c$ ?

## Copernican Revolutions



1. We are not the center of the Solar System.
2. We are not the center of the Galaxy.
3. We are not the center of the Universe.

## Our First View



- The first concepts of the Universe were Earth-centered.
- How did we come to this point—Astro 330?
- First recorded cosmology was from the Babylonians.
  - The Universe is a large oyster, and we are inside.
  - But other aspects of their astronomy was advanced.
  - Regularity of astronomy for crop planting, harvesting, and accurate calendars back to the 3800 BC.



<http://www.internationalenglish.co.uk/courses.htm>

## Our First View



- The Mayans computed the length of year to within a few seconds (0.001%).
- So early humans had a weird mixture of precise calendar astronomy with primitive concept of the Universe and mythological systems incorporating magic.



<http://www.mayasites.com/equinox.html>



<http://ephemeris.com/history/mayan-calendar.jpg>

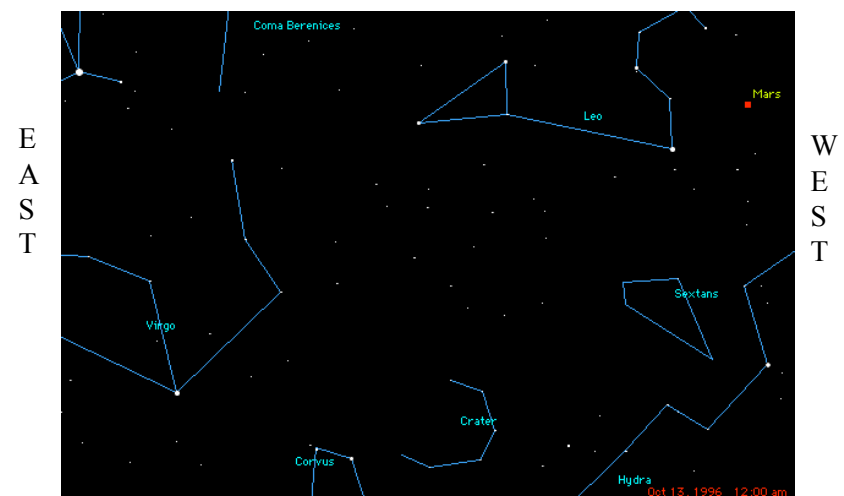
## Greek Astronomy



- Greeks were excellent Astronomers
  - Cataloged star positions & brightness.
  - Systematic, quantitative observations.
  - Natural philosophers.
- They observed that the stars, Sun, and planets revolved around the Earth.
- So Earth is center of Universe—**geocentric cosmology** (mostly from Plato and Aristotle).
- Even though other philosophers (Aristarchus) argued for a heliocentric cosmology.
- Perfect Spheres of motion?



## Mars Moves WRT the Stars!



The backwards motion is called retrograde motion.

## Motions of Planets



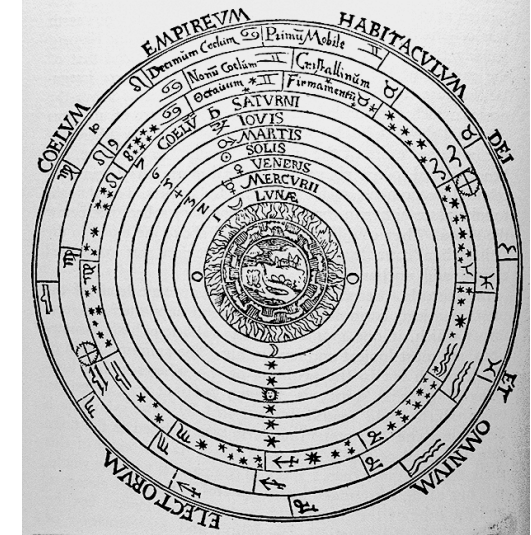
- So, over time the planets seem to move along the ecliptic from west to east over long time periods.
  - This is called **prograde** motion
  - Note that they still rise in the East and set in the West each day. We are referring to their relative motion wrt the stars.
- But once in a while, a planet appears to stop and reverses direction
  - Reverse direction is called **retrograde** motion (east to west).
- Planets move counter-clockwise (looking down at the north pole)

## How can we explain the Planet motion?



But with a **geocentric cosmology** you can't easily explain the retrograde motion of the planets.

Note: perfect circles



## Ptolemy (140 AD: 'p' is silent)



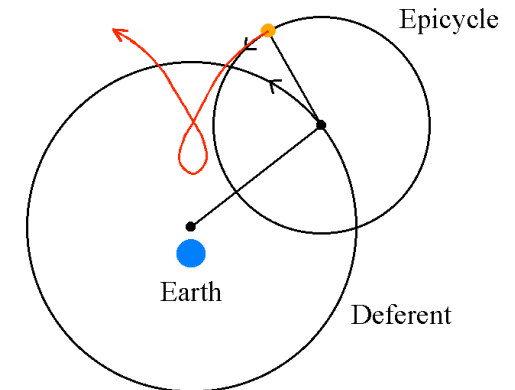
Took **geocentric** model with uniform circular motion to introduce the Ptolemaic system, or model, of the Solar System that explained **retrograde** motion



## Ptolemaic system



- Geocentric
- Nice circular motion

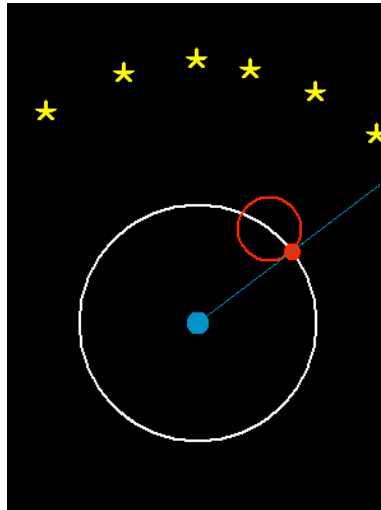




## Ptolemaic system



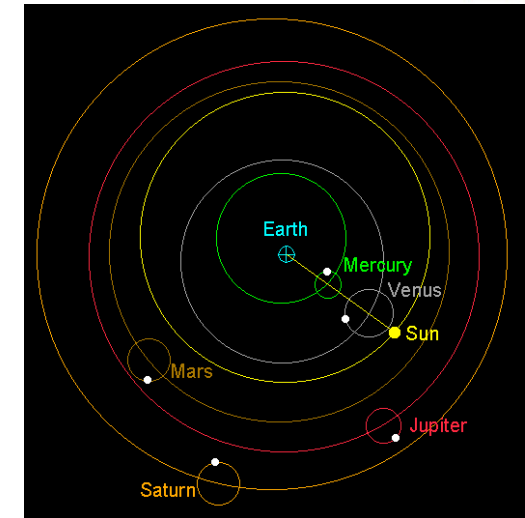
**Yes, it can  
explain  
retrograde  
motions**



## Ptolemaic system



Overall system of  
the Solar System.

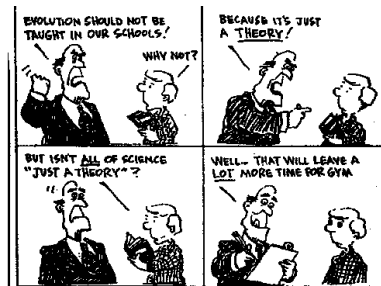


## Ptolemy's Geocentric Cosmology: *Is it a Scientific Theory?*



**Yes!** ...and an accurate one too

- Data: Sun/moon/star motions
- Tentative Model: circular orbits
- Prediction: uniform motion on sky
- New data: retrograde motion
- Refined model: epicycles  
– explains data!



<http://home.comcast.net/~fsteiger/theory.htm>

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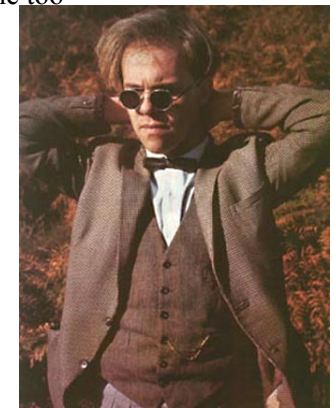


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**Result:** Ptolemaic system (theory)

- *Strength:* accurate fit of data
- *Weakness:* predictions for new data?

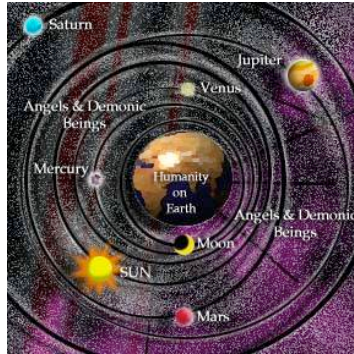


<http://www.tmdrfan.com/rthurlow/ThomasDolby1982.htm>

## Ptolemaic Problems



- Each planet acted independently of others
- There was no universal rule governing the planets motions.
- Nonetheless, for a 1000 years this model ruled western thought
- However, by the late middle-ages astronomers felt that it was too complex, and a search began for a system with simple underlying principles



<http://gbgm-umc.org/umw/bible/images/ptolmai2.jpg>

## Question



The main problem with an Earth centered Solar System are the retrograde motions of planets. It was solved by

- Allowing the planets to move on orbits on orbits.
- Moving the Earth off the center a little bit.
- Perfectly circular orbits.
- Elliptical orbits.
- Superman making the Earth turn backwards.

## Question



In the Ptolemaic system, if a new planet was found, then

- its orbit could be quickly found based on the other planets.
- one could predict its epicycle and deferent .
- one could figure out an epicycle and deferent to make the orbit work.
- one could predict the location of other unknown planets.
- it would have broken the Ptolemaic system.

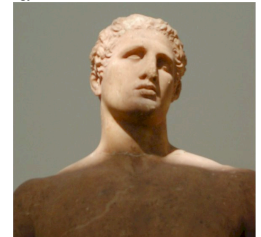
## Lessons: Were the Greeks Stupid?



- Not at all!  
Developed sophisticated, successful model
- But built in prejudices about the world  
not just geocentric but egocentric

What about scientists today?  
Still can fool ourselves! (And have!)  
But: *scientific method* is tool:

- To keep from fooling yourself
- To correct yourself when you have



[http://www.farhorizon.com/europe/images/images-greece/head\\_of\\_Greek\\_god.jpg](http://www.farhorizon.com/europe/images/images-greece/head_of_Greek_god.jpg)

## Lessons: Were the Greeks Stupid?



### My guess:

70% of the material in this course will stand the test of time

- Compare baseball: 70% success is very good
- But also: 30% of course is wrong/incomplete!
  - Which 30%? Don't know! Would fix it if we knew! So...
  - You have to learn all of it!



[http://sportsillustrated.cnn.com/baseball/mlb/specials/spring\\_training/2007/previews/cubs.html](http://sportsillustrated.cnn.com/baseball/mlb/specials/spring_training/2007/previews/cubs.html)

## Power of Ignorance



- Geocentric model was absorbed by Christianity.
- If Geocentric, then of course no ET life.
- St. Augustine (420 AD) incorporated Neo-Platonism. He listed science as a temptation to avoid: “a mere itch to experience and find out”
- Also said, “Nor do I care to know the course of the stars.”



[http://www.floolocaustmuseum.org/history\\_wing/assets/room1/St\\_Augustine.jpg](http://www.floolocaustmuseum.org/history_wing/assets/room1/St_Augustine.jpg)

## Power of Ignorance



- The European worldview degenerated for years.
- No one in Europe mentioned the supernova of 1054 (Crab Nebula), unlike China or Americas. People were afraid to notice it and be described as a heretic.
- Could an ET civilization reach technology with that sort of attitude?

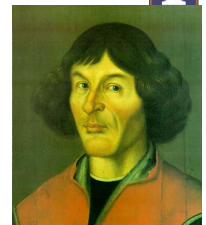
<http://www.pbs.org/deepspace/timeline/t114.html>



<http://www.godandscience.org/images/crabnebula.jpg>

<http://www.tulane.edu/~danny/southwest.html>

## Copernicus (1540) resurrected the heliocentric model



- If Earth moves, then stars have to be very far away.
- Was rejected on theological and philosophical grounds.
- 1616, the Catholic Church listed it as heresy.





## Giordano Bruno



- Took this one step further.
- Thought that the stars were all little Suns.
- Possibly with planets of their own.
- Maybe life on those other planets.
- Maybe more advanced than those on Earth.



## Giordano Bruno



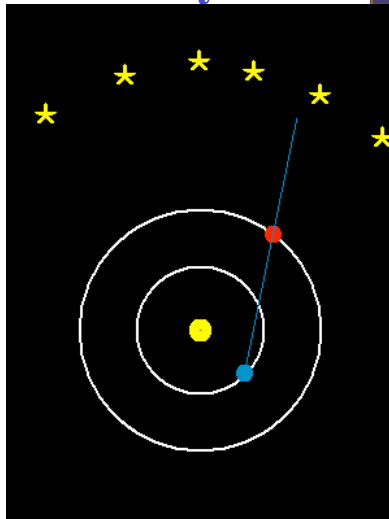
- These are some of the reasons why he was tortured then burned at the stake around 1600.
- One of his crimes of heresy: “Claiming the existence of a plurality of worlds and their eternity.”
- He became a martyr for free-thought in the 19<sup>th</sup> century.



## Copernican Theory



- Can explain retrograde motion
- Much simpler
- Still kept to circular motion
- Eventually changed the way we think of ourselves!



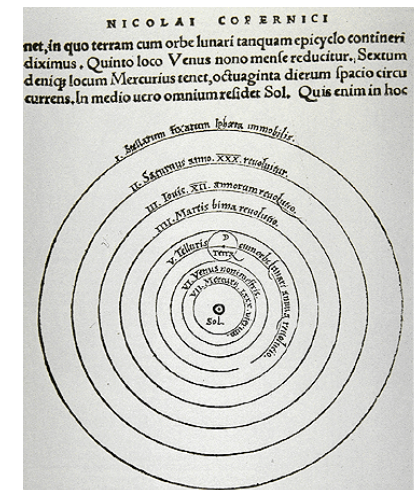
## Copernicus (1540) Heliocentric Model



BUT, keep in mind that the geocentric model was still valid. Both models explained the observed motion.

Heliocentric is NOT obvious!

It was determined a philosophical argument for 50 years! New observations were required to determine which is correct.





## Tycho Brahe (1580): Uraniborg



Accurate measurements to about 1 minute of arc (1/15 the diameter of the moon). No telescopes!



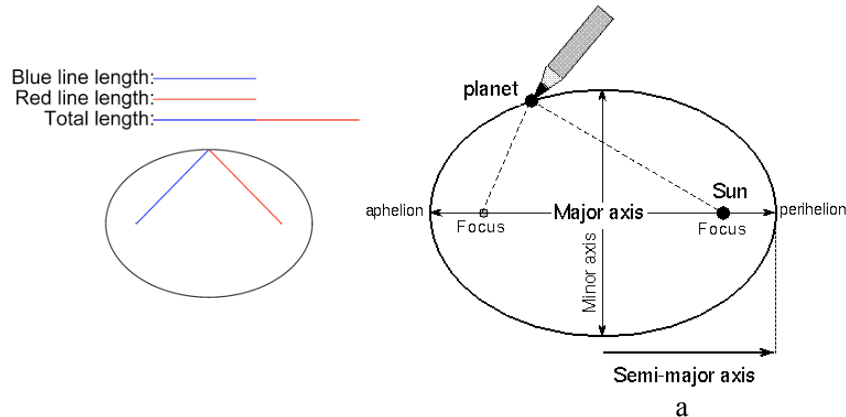
## Johannes Kepler (1600)



- Tycho's assistant in Prague
- After Tycho's death, succeeded Tycho's position and had access to the excellent data
- How to fit the Heliocentric model to accurate data of Mars?
- Circles didn't work.
- Ellipses!



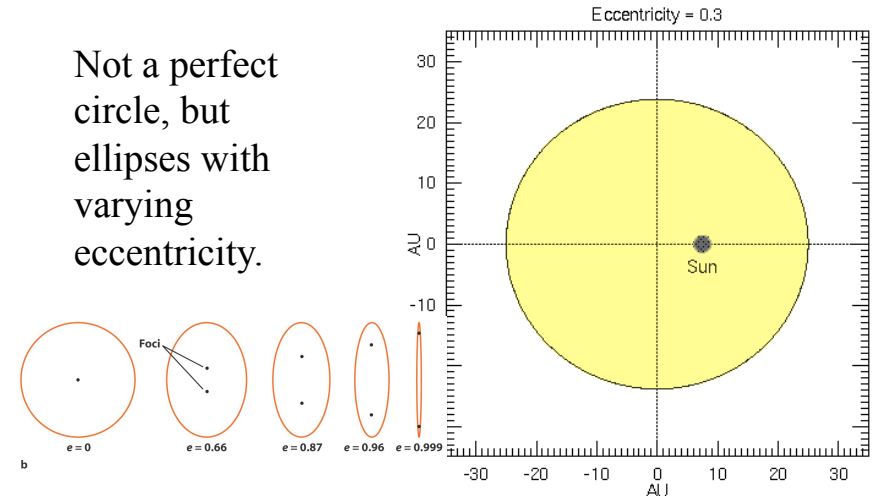
## Kepler's 1<sup>st</sup> Law: Orbits of planets are ellipses with the Sun at one focus



## Orbits of planets are ellipses with the Sun at one focus



Not a perfect circle, but ellipses with varying eccentricity.

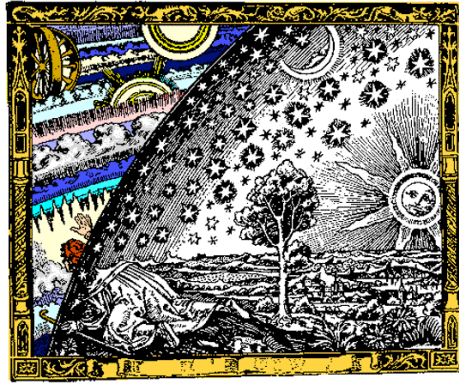




## Implications



New Twist— even the Sun isn't at the center of the solar system now. How does that change our view of the Universe and our place in it?



<http://antwrp.gsfc.nasa.gov/apod/ap010101.html>

## Galileo (1609) 400 Years!



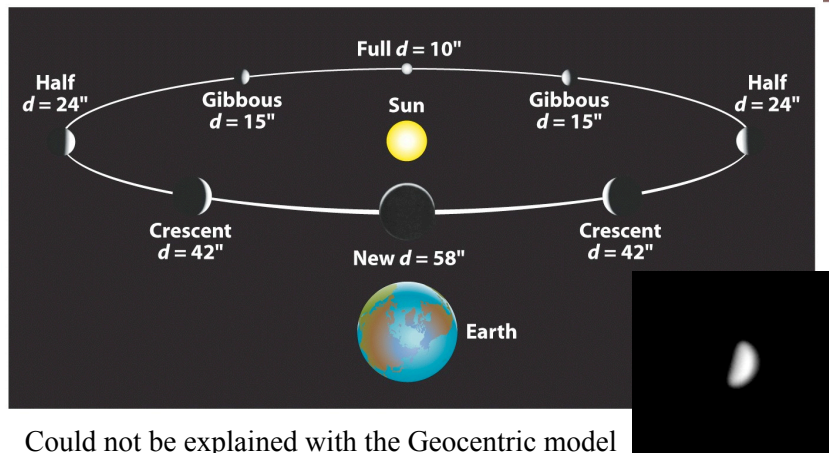
First to systematically use the telescope (but did not invent it).

- Moon has mountains and valleys
- Milky Way consists of faint stars
- Saturn is elongated
- Venus shows phases
- Jupiter has moons (now called Galilean moons)

Wow! Big stuff. The moons of Jupiter did not orbit the Earth!



## The Phases of Venus



Could not be explained with the Geocentric model

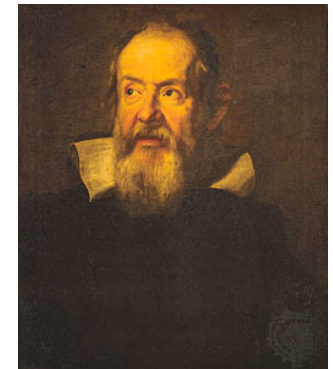
<http://www.astro.ubc.ca/~scharein/a310/SolSysEx/phases/Phases.html>

<http://www.calvin.edu/academic/phys/observatory/images/venus/venusb.html>

## Galileo (1610)



- Disproved Ptolemaic system
- Rome bullied him into recanting (cleared in 1992)
- Now we understand the motions and the fact that the solar system MUST be Heliocentric, but now we need a reason why?
- Need something with predictive power.



## Isaac Newton



- Gave us a reason why-- GRAVITY.
- Developed fundamental laws of nature.
- Now, we had a reason why the Solar System objects moved.
- And we could predict new objects!

## $f_c$ Your Guess!



- Given that an intelligent civilization exists, what is the likelihood that it can (technologically advanced) and will want to (knows astronomy and thinks that its chances are good) communicate?
- Cultural evolution to technology and worldview are essential components of  $f_c$ 
  - Extra-somatic storage of info crucial.
  - Technology and innovation– quantum mechanics
  - Copernican revolution played an important role.
  - ET has to realize that they are not the center of the Universe and that there might be other life.
  - How fast were these accomplishments? What is fast?

## Big Questions for $f_c$



- Our capacity for interstellar communication arose at the same time as our interest in it. Coincidence?
- Can a society have a highly developed technology with an incorrect astronomy?
- What if the skies were constantly cloudy?
- What if their solar system had no other planets?
- What if they lived in a molecular cloud?
- What if they lived in a huge cluster of galaxies?

## $f_c$ Development



- Are we typical?
- Is it inevitable  $f_c = 100\%$  or a fluke  $1/10000$ ?
- Remember civilizations come and go, but in general the gains (technology/worldview) aren't lost.
- Picked up by the next civilization.
- Even if one civilization goes dark for centuries, eventually another rekindles the technology/worldview.
- We are talking about the ability to communicate, not that the civilization is communicating.

## Drake Equation

That's 8.2 x ? Communicating life/century

Frank Drake



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
9	stars/yr	0.29	systems/star	1.03 x 0.22 = 0.23	0.46	0.3	life/planet
				life/planet	intel./life	? comm./intel.	yrs/comm.

## Lifetime of Civilization

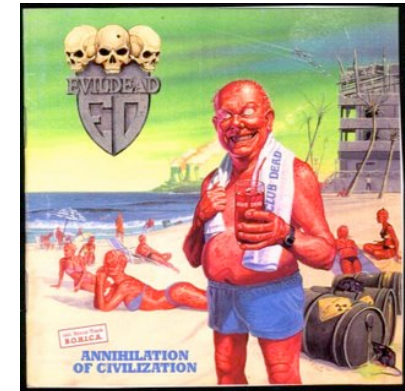


- This factor pulls a lot of weight in the Drake equation. Are we alone or are there aliens everywhere?
- Easy to envision 4 cases:
  - Communication efforts stop. Bored with lack of success or funding issues.
  - Civilization evolves away from interest or capability. But empires rise and fall.
  - Technological civilization collapses: exhaustion of resources and population growth,
  - Catastrophe! Nuclear war or various natural problems.

## Lifetime of Civilization



- If a civilization can communicate with other life forms, and wants to, how long can it last?
- We are taking about the long haul here, not necessarily short time scales.



## Killer Skies: Astro-Disasters

(Top 10 Ways Astronomy Can Kill You or Your Descendants)  
Astro 150, Fall 2010: Leslie Looney

- Are you scared? Should you be?
- Exploration of the most dangerous topics in the Universe, such as meteors, supernovae, gamma-ray bursts, rogue black holes, colliding galaxies, quasars, and the end of the Universe, to name just a few.
- A fun class that does not require any prereqs, except an open mind!
- Counts as a Physical Sciences course.





## Issues



- The last 2 items:
  - Technological civilization collapses
  - Catastrophe
- Could be caused by:
  - Resource Exhaustion
  - Population growth
  - Nuclear war
  - Natural catastrophe
  - Other...

Hiroshima

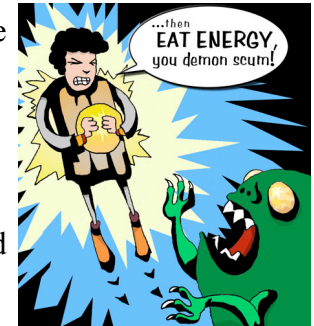


<http://gawain.membrane.com/bew/Japan/Hirosh.html>

## 1. Depletion of Resources



- Modern life depends on metals and rare elements.
- Recycling can delay the depletion.
- Pollution of our water or air supply is still a problem.
- But, many of these issues can be solved with sufficient **energy**.



<http://www.timboucher.com/portfolio/eat-energy.jpg>

## 1. Depletion of Resources



- Energy allows us to recycle, remove salt from the oceans, grow more crops, and generally convert material into the form we need.
- So, energy is our **greatest** concern.
- Remember that energy is not depleted, rather converted from useable form to less useable form (2<sup>nd</sup> law of Thermodynamics).



<http://europa.eu.int/comm/mediatheque/photo/select/energy/p-009892-00-8h.jpg>

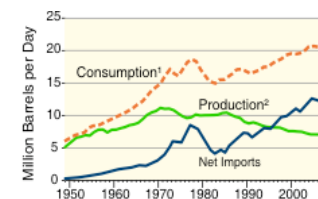
## Energy



- Majority from chemical means– fossil fuels– electricity and gasoline (92% in the U.S.).
- Really are from fossils, representing millions of years of life.
- And how are we spending it?
- The average US citizen uses twice that of a European, and 5 times the world average.



<http://www.orps.state.ny.us/sas/graphics/oilwells.jpg>



<sup>1</sup>Petroleum products supplied is used as an approximation for consumption.  
<sup>2</sup>Crude oil and natural gas plant liquids production.  
 Source: Energy Information Administration, Annual Energy Review 2007–Table 5.1. (June 2008)

[http://tonto.eia.doe.gov/energy\\_in\\_brief/foreign\\_oil\\_dependence.cfm](http://tonto.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm)

## Energy

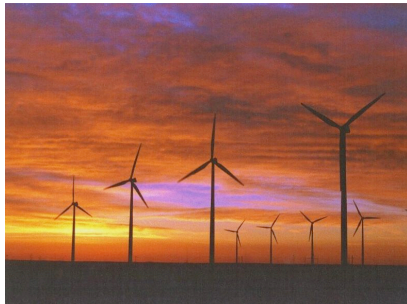


- Easy to obtain fossil fuels should last 50-100 yrs, coal 300-600 yrs.
- We will have to change! But US spending on renewable energy sources dropped by factor of 10 in the 1980s.
- SUVs do not help.



<http://www.orps.state.ny.us/sas/graphics/oilwells.jpg>

<http://www.astrosurf.org/lombry/Documents/windfarm.jpg>



[http://www.dealerimpact.com/downloads/desktop\\_imgs/800x600-hummer.jpg](http://www.dealerimpact.com/downloads/desktop_imgs/800x600-hummer.jpg)

## Nuclear Fission



- Breaking apart heavy (heavier than iron) unstable elements into lighter ones. Like an Un-Sun.
- Most widely used is  $^{235}\text{U}$ —formed from supernovae—so limited amount on Earth.
- Supplies are limited and length of use controversial.

### Nuclear Fission Chain Reaction

- —  $^{235}\text{U}$
- — Neutron
- — Fission Product



<http://library.thinkquest.org/17940/texts/images/chainreactionanim.gif>

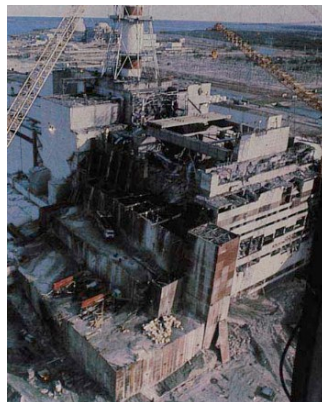


<http://www.capefare.com/seasonone.php>

## Nuclear Fission



- A large reactor power plant uses 26 tons of fuel and 25 tons of waste per year.
- What do we do with the waste?
- How to prevent accidents: Three Mile Island or Chernobyl?

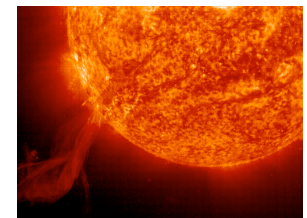


<http://www.ourtimelines.com/hist/chernobyl.jpg>

## Nuclear Fusion



- What the Sun does for energy— $\text{H} \Rightarrow \text{He}$ .
- Requires high density and temperature.
- How to contain it on Earth—Sun uses gravity.
- Put the Sun in a box, but how to build that box?



<http://antwrp.gsfc.nasa.gov/apod/ap051109.html>  
<http://www.cnn.com/SHOWBIZ/9712/24/teletubbies/>  
[http://www.pppl.gov/fusion\\_basics/pics/fusion\\_dt\\_reaction.jpg](http://www.pppl.gov/fusion_basics/pics/fusion_dt_reaction.jpg)

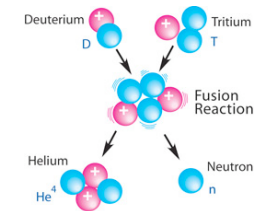


Diagram of deuterium-tritium reaction.

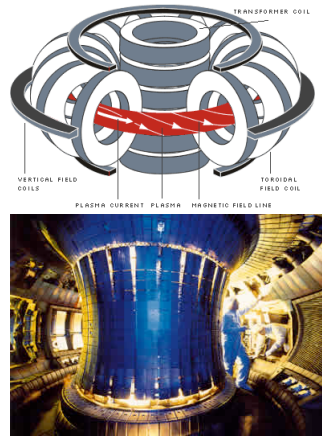


## Nuclear Fusion



- Magnetic confinement, but not easy.
- Research continues, but unlikely to play a large role in the next 50 yrs.
- And on Earth requires deuterium (heavy hydrogen) not as abundant as hydrogen, nonetheless very promising!

Tokamak Fusion Reactor

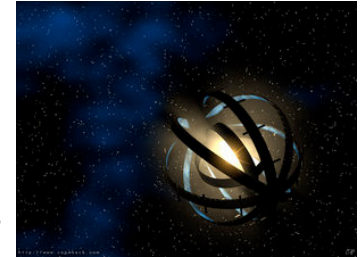


<http://www.ipp.mpg.de/ippcms/eng/pr/exctypen/tokamak/magnetspulen/index.html>

## Long-Lived Civilizations



- Require renewable energy supplies, all Sun related.
- Hydroelectric (requires rain), windmills (winds), and solar power.
- Solar power is used today, but currently expensive because of manufacturing and tax subsidies for fossil fuels.
- Future example, could imagine a power plant that completely surrounds the Sun— e.g. Dyson sphere.

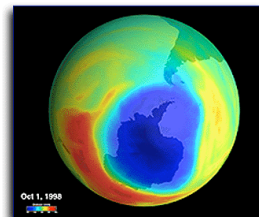


<http://capnhack.deviantart.com/art/Dyson-Sphere-11008136>

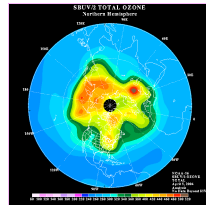
## Pollution from Civilization



- Ozone layer ( $O_3$ ) is formed from  $O_2$   
 $O_2$  broken up by ultraviolet light
- Ozone protects life against harmful Sun rays.
- Chlorofluorocarbons (CFCs) destroy the ozone.



ANTARCTIC OZONE HOLE  
PHOTO COURTESY OF NASA



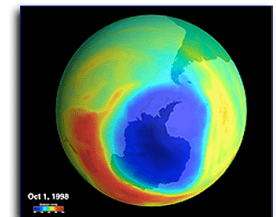
[http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif\\_files/sbuv16\\_nh\\_latest.gif](http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif)

<http://www.ngdc.noaa.gov/paleo/globalwarming/images/ozone.gif>

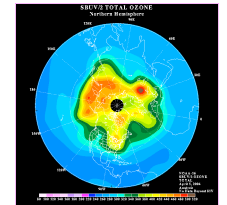
## Pollution from Civilization



- CFCs were used in A/C and refrigeration.
- Governments did not do much until a large hole appeared over Antarctica and N. America.
- Finally, being phased out, but the CFCs take about 20 yrs to reach stratosphere.
- The problem was predicted 25 years ago.



ANTARCTIC OZONE HOLE  
PHOTO COURTESY OF NASA



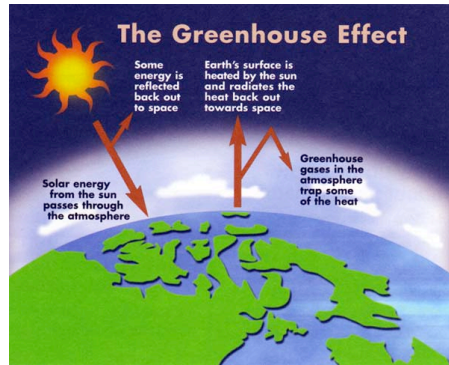
[http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif\\_files/sbuv16\\_nh\\_latest.gif](http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif)

<http://www.ngdc.noaa.gov/paleo/globalwarming/images/ozone.gif>

## Global Warming



- Burning of fossil fuels releases CO<sub>2</sub>.
- This is a greenhouse gas.
- Humans add more CO<sub>2</sub> to the atmosphere (50-100x) than natural sources— 25 billion tons each year!



[http://www.climatechange.gc.ca/english/climate\\_change/images/ghg\\_effect\\_lg\\_e.jpg](http://www.climatechange.gc.ca/english/climate_change/images/ghg_effect_lg_e.jpg)

## Question



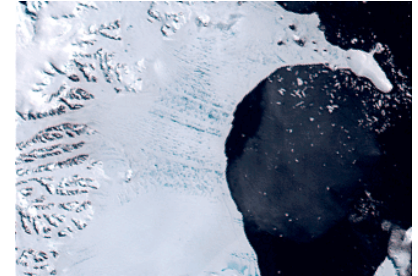
Although depletion of resources is a major issue for long term survivability of an advanced civilization, resource depletion really highlights a larger issue,

- a) energy.
- b) population growth.
- c) global warming.
- d) pollution.
- e) asteroids.

## Global Warming



- Why hasn't the temperature rise been more dramatic?
- The burning of coal releases sulfates form a haze that increases the albedo of Earth.
- So the effect is less than expected, but predictions suggest that CO<sub>2</sub> content will begin to dominate in this century.
- Already, large slabs of the Antarctica ice shelf have melted.



Destruction of Larsen ice shelf 2002. 3250 km<sup>2</sup> over 35 days. That's bigger than Rhode Island! Existed for at least 400yrs maybe 12,000yrs.

<http://www-nsidc.colorado.edu/iceshelves/larsenb2002/animation.html>